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ABSTRACT

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The design of a plasma gun (ref. 1) has been used to produce high peak values of electron current. Investigations of the effect of all parameters on the electron current have been made, and the possibilities of a plasma gun determined. AUTHOR

A source of electrons with a high peak value of electron current /139*
(150-200 A) and a relatively low energy (up to 1 Mev) is required for a number of experiments in physics. The production of such currents has so far been difficult from a technical point of view. The electron guns used in klystrons are complicated electronic devices, and the service life of their cathodes is, as a rule, sharply limited.

A consideration of the known methods of producing electron beams with a high peak current was followed by a decision to create an electron gun on the basis of the spark plasma source developed by the physiotechnical institute of the Georgian Academy of Sciences (refs. 1 and 2); it had been successfully used for the

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* Numbers given in margin indicate pagination in original foreign text.

production of multicharge ion beams. The authors have investigated the possible use of such a gun for generating large electron currents.

The electron source (fig. 1) represents a system of three electrodes; discharge electrode 1, diaphragm 5 and suction electrode 6 mounted on two stainless steel discs. Plexiglass tube 4 (working substance) and spring 8, which is used to extend tube 4 into the clearance as it burns out, are fitted over discharge electrode 1 which is made of a ϕ 3 mm tungsten rod. The discharge electrode is inside the porcelain tube 3 which provides the necessary electrical insulation. The diameter of the tungsten disphragm opening is 1 mm. An intermediate electrode, cathode 2, which is insulated from the ground, is used to improve the /140 suction conditions and the suction field focusing. The insulation is designed for 25-30 KV. The suction electrode is shaped like a stainless steel cylinder and is located under the ground potential.

When the +17-kV potential is fed to the discharge electrode by a discharger, a spark discharge which causes the evaporation of the working substance develops between the discharge electrode and the diaphragm. The plexiglass evaporation in chamber 7 produces a plasma which is channeled into the effective clearance by the pressure difference in the chamber and vacuum space. There the electrons are drawn out of the plasma under the effect of the electric field. The power supply system is shown in Fig. 2. A "trigatron"-type discharger is used in that system.

The effect of the basic source parameters on the electron current was investigated for the selected design of the source. In particular, a reading was taken of the dependence of the electron current on the discharge voltage for the fixed value of the suction voltage. The relation between the electron current and the discharge voltage, in the case of various distances from the cathode to the

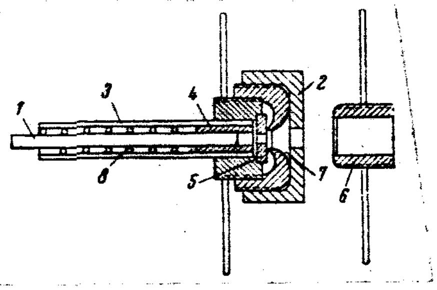

Figure 1. The designs of the source. 1-discharge electrode; 2-cathode; 3-porcelain tube; 4-working substance; 5-diaphragm; 6-suction electrode; 7-chamber; and 8-spring.

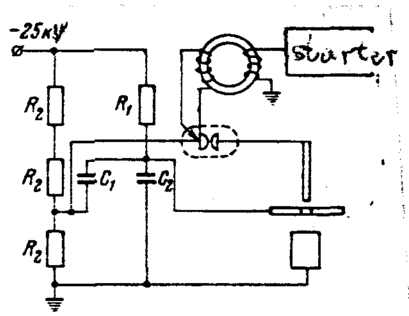

Figure 2. The supply system of the source.

suction electrode (h) is shown in fig. 3. The distance from the discharge electrode to the diaphragm was found to be constant (3 mm), and this explains the diminishing electron current with the increasing discharge voltage above 16 kV. Higher discharge voltages led to a breakdown of the discharge electrode-diaphragm air space which reduced the evaporation of the working substance as well as the density of the plasma.

The dependence of the electron current on the suction voltage was also measured. This dependence is shown in fig. 4 with reference to a characteristic suction electrode-diaphragm clearance (curve I). The $I \sim U^{3/2}$ dependence (curve II) is shown in the same figure for comparison purposes. The diaphragm diameter has

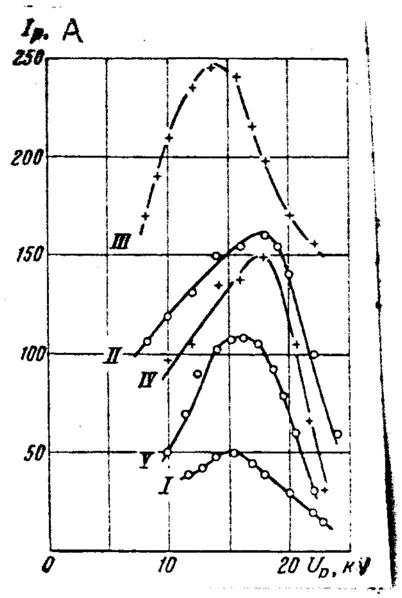

Figure 3. Curves $I_e = f(U_p)$: I - h = 6.5 mm; II - h = 7.3 mm; III - h = 8.2 mm; IV - h = 11 mm; V - h = 14 mm.

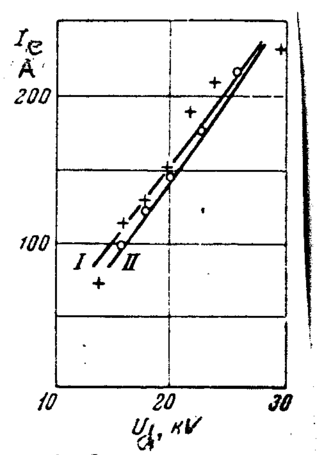

Figure 4. Curve $I_e = f(U_d)$; U_p = 16 kilovolt; h = 8.5 mm.

a substantial effect on the magnitude of the electron current. A reduction in the size of the diaphragm is conducive to a greatly weakened electron current. Larger diaphragms require a change to longer distances to the suction electrode and to higher suction voltages.

The selection of the optimal source parameters resulted in the generation of a 200-ampere electron current. The duration of the current pulse was 0.15-0.2 microseconds. The measurement of a short-duration and high magnitude electron current involves a number of difficulties associated with the proper selection of the measuring resistances and the inductance effect of the power-supply wires. In this case the situation was complicated by a very high level of induction from the discharge current, which made an effective shielding highly important. We tested several measuring devices of different designs with a view to avoiding measuring errors.

The results were checked by making measurements involving the use /141 of several variants of the Rogovskiy Belt. Particular attention was focused in the course of the measurements on the resistance structure when working with Faraday cups. Specially produced resistances were used in addition to the ULI resistance. A Silit resistor was made in the shape of a tube with the braiding of a high-frequency cable soldered to one end of it. The cable conductor was passed through the tube and soldered to its other end. Such a design reduced the inductance of the measuring circuit to a considerable extent. Coaxial shunts were also used for measuring purposes. All this made it possible to get reliable measurements of the magnitude and shape of the current.

The resonance transformer used for accelerating the electrons has a relatively low power reserve, and cannot accelerate any durable and high (100 amps) electron currents without a marked change in the energy of the accelerating electrons.

In our case the duration of the current should be 10^{-8} sec in order to get a 5% energy straggling in 100-ampere electron beam. The source should fairly well tie into the phase of the high-frequency voltage ($5 \cdot 10^{-9}$ sec.) and possess a steep front of rising current. These requirements substantially reduce the possible utilization of the above-described source, as the rate of the rising electron current is determined by the rate of plasma-formation. It was therefore impossible to get a duration of the electron current build-up of $<50 \cdot 10^{-9}$ sec. Furthermore, the operation of the source revealed an instability of the electron current amplitude.

Returning to the description of the source's operation, it is not difficult to see that the continuously effective suction field draws off the electrons not only during the plasma-forming peak but also in the initial period, when there are still very few electrons in the plasma. This is explained by the insignificant steepness of the current pulse front. It was therefore proposed to draw off the electrons from the heated part of the plasma with the steady-state parameters with a view to eliminating the mentioned shortcomings. This suction of the electron current was made possible by supplying a delayed pulsed suction in relation to the discharge current. The use of a pulsed suction facilitated a considerable increase in the gradient of the suction field.

The structural parameters of the source with a pulsed suction were the same as in the case of the direct current suction, and the above-cited characteristics were therefore used in the selection of the optimal working conditions for the source. In addition, the dependence of the electron current on the delay time of the suction voltage in relation to the discharge current was eliminated. The current reaches its maximum value when delayed $1.6 \cdot 10^{-6}$ sec. Shown in fig. 5 are the current pulses taken off at various delay times close to the optimum.

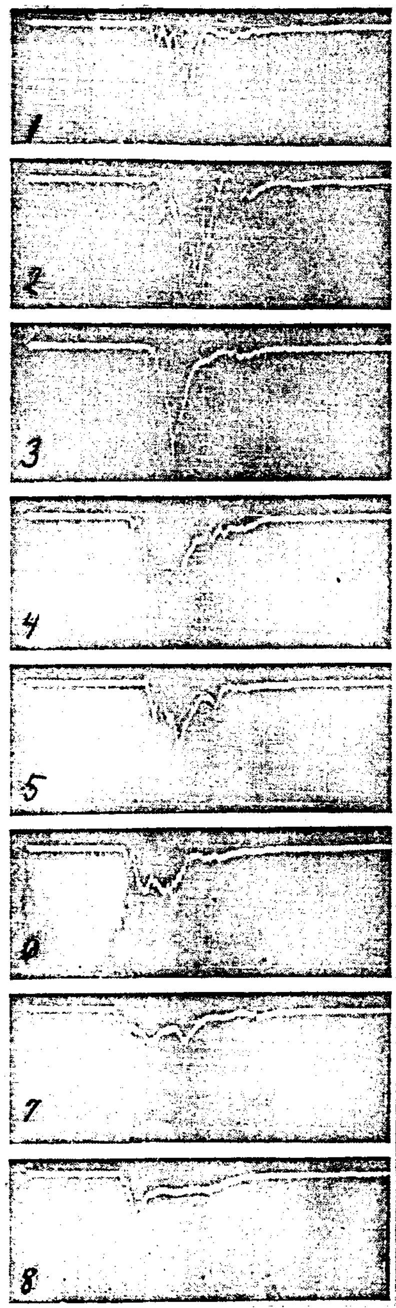

Figure 5. Oscillograms of electron current pulse τ_p = 200 millimicrosec /cm. With t_z equal to: 1 - 1.0 millimicrosec; 2 - 1.2 millimicrosec ; 3 - 1.4 millimicrosec ; 4 - 1.6 millimicrosec ; 5 - 1.8 millimicrosec ; 6 - 2.0 millimicrosec ; 7 - 2.2 millimicrosec ; and 8 - 2.4 millimicrosec.

The discharge current, the suction pulse delayed in relation to the discharge and the drawn-off electron current are shown in fig. 6. In the case of a pulsed suction the steepness of the current pulse front is determined by the steepness of the suction pulse front. The suction pulse in operation, as well as the current pulse, are somewhat distorted because of the inductive reactance of the power supply wires and the capacitance of the wiring; it is therefore desirable to have a source of suction pulses with a minimum characteristic impedance of $\sim 1 - 5$ ohms. Capacitances which, as a rule, have their own inductance are used as a source of suction pulses in the system under discussion. The authors have investigated the effect of various types of condensers in /142 the suction circuit on the shape of the current pulse (fig. 7).

FGTI and KV condensers make it possible to obtain $\tau \phi \sim 150$-200 millimicroseconds, and the KOB-3 condenser 10 millimicroseconds. The suction pulse was supplied from an artificial shaping line with a $\sim$ 8-ohm wave impedance in order to generate a longer electron current pulse by means of the given source. The elimination of the electron current dependence on the suction voltage /143 revealed on $I \sim U^{3/2}$ regularity. A maximum of a 600-ampere electron current was generated when the force of the suction amounted to 60 kilovolts. The distortion of the pulse shape with the increasing current amplitude is due to the insufficient discharge and suction capacitance. The shape of the pulse is restored by an increase in capacitance. An increase in the discharge capacitance changes the optimal plasma section in the direction of longer periods.

The investigations have revealed the possibility of generating electron currents up to 10^{-6} sec duration by means of a spark source of one kiloampere and higher.

In conclusion, the authors express their gratitude to P. F. Chernyayev for his large contribution to the development of the experimental installation.

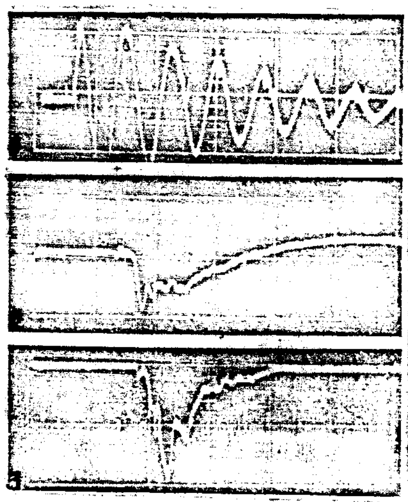

Figure 6. 1-discharge current τ_p = 500 millimicrosec /cm; 2-suction pulse τ_p = 200 millimicrosec /cm; and 3-electron current pulse τ_p = 200 millimicrosec /cm.

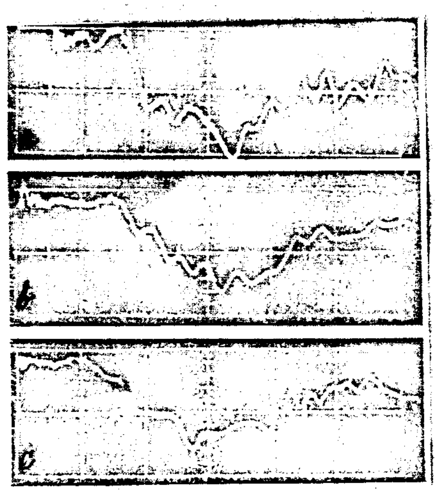

Figure 7. a-S_{suct} = 10 nϕ (KOB-3); b-S_{suct} = 10 nϕ (KV-10); c-S_{suct} = 10.8 nϕ (FGTI); τ_p = 100 millimicrosec /cm.

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